Elementary cycling

Cycles of Life: Civilization and the Biosphere
by Vaclav Smil
Scientific American Library/W.H. Freeman: 1997. Pp. 221. $32.95, £19.95

Mike Whitfield

If the whole of the Earth's history were compressed into a day, the residence times of most of the essential elements in the atmosphere, oceans and biosphere would be measured in fractions of a second. Only by parsimonious recycling and careful reutilization of elements could life persist and evolve in the face of such dynamic change. Smil's book addresses the biological cycling of just three elements — carbon, nitrogen and sulphur — which are essential to life and are effectively recycled in soluble waterborne compounds as well as in gases.

When dealing with terrestrial and atmospheric cycles, the book is authoritative and detailed, and is a pleasure to read. The way the cycles work, the evolution of our understanding of their intricacies and the interference of civilization in their functioning are traced in clear language, and with beautifully presented diagrams and photographs. Nicely drawn dioramas or complex and intricate flowcharts illustrate the global cycles themselves. Frustratingly, fluxes and reservoir sizes are given only on subsets (Antarctic carbon cycle or Chinese agricultural nitrogen cycle) that are atypical of the global system.

A readily digestible analysis is provided of such complex issues as soil and water acidification and the fertilization of terrestrial plant growth by industrially released carbon dioxide and oxides of nitrogen. The folly of reaching for technofixes to alleviate such problems is emphasized most tellingly in an account of the intensification of the acid-rain problem in the United States that resulted from concerted efforts to clean up power-station discharges.

The author is less sure footed when dealing with the marine system. This is unfortunate because the oceans cover two-thirds of the Earth's surface, and for the first eighty per cent of the Earth's history provided the only environment of any significance. The role of the oceans in the carbon cycle is given fullest coverage, though even here the treatment is oddly skewed at times. For example, the focus on the Antarctic carbon cycle leaves the false impression that, globally, birds and mammals form the main route for the transfer of carbon dioxide from the oceans to the atmosphere, and that only ten per cent of the carbon dioxide fixed by phytoplankton passes through the bacterial system.

The marine cycling of nitrogen gets short shrift. It is not included in a neatly presented history of our understanding of the nitrogen cycle, and the only mention within the chapter called "Reactive Nitrogen in the Biosphere" is an unexplained link between nitrate discharge and the crown-of-thorns starfish plague on the Great Barrier Reef. The production of dimethyl sulphide in the oceans is mentioned, but there is no overall budget for the global sulphur cycle to allow its impact to be assessed. Furthermore, its involvement in influencing cloud albedo over the open oceans, a matter of intense study and debate, is dismissed as unimportant, even in the preindustrial world, for the rather odd reason that burning vegetation also generates cloud-condensation nuclei. These criticisms are alleviated to some degree by an excellent treatment of the prob-

In retrospect chosen by Keith Stewart Thomson

Natural Theology; or Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature
by the Reverend William Paley
(1802)

The alternative concepts to evolution are teleology and the argument from design, which is the proposition that the intricacies of nature and the supposed perfection of an organism's adaptation to the conditions of its existence (a darwinian term) are evidence of the operation of a First Cause, God the Creator. Paley's classic exposition of this subject has enjoyed almost as many editions and readers as Darwin's *On the Origin of Species.* Not that the argument from design was original to Paley; indeed a contemporary reviewer even asked why another work on this subject was necessary (*Edinburgh Review*, vol. 1, 1802–1803). As an undergraduate, Darwin himself was impressed by Paley's logic, although not unconditionally ("I did not at that time trouble myself about Paley's premises").

Natural theology is not so much a religious argument against the rising sciences of the early nineteenth century as a marshalling of scientific evidence against various forms of atheistic materialism. Paley's targets are David Hume, unitarians, deists and other free-thinkers including Buffon and, of course, Erasmus Darwin, and all notions that the natural world is the product of chance or the blind workings of laws and principles.

The trouble with Paley's argument is not its form, and certainly not its brilliant opening syllogism: a watch is found on the ground, "we perceive... that its several parts are framed and put together for a purpose...(and) the inference, we think, is inevitable, that the watch must have had a maker." Therefore complex organisms must also have had a maker. (A similar argument was made by Cicero in *De Natura Deorum.*)

Paley must next imagine that a watch could be found that contained within it the makings of more watches ("... a complex adjustment of lathes, files, and other tools evidently and separately calculated for this purpose"), and now the downhill slide begins. Just as a hypothesis that explains everything explains nothing, so a Creator who has created everything has created too much. The First Cause cannot have unintended consequences, so Paley is left wriggling on his self-imposed hook: why did God create pain and suffering, war, pestilence and famine? (For Darwin, the heartbreaking death of his daughter Annie turned him against religion as much as any science.)

Paley, writing as a scientist rather than a theologian, takes some of his answers from Thomas Malthus (*An Essay on the Principle of Population*, 1798). For example, the malthusian inevitability of poverty "necessarily imposes labour, servitude, restraint". This natural cause of class structure forms a convenient argument against all kinds of disturbing movements of self-improvement. Where Malthus argued that utopian communities were impossible, Paley has to argue that we (blessed are the poor, indeed) live in one.

Malthus explains the harsh exigencies of the natural world, and Paley's works (which Darwin studied intently and partially memorized) thus gave Darwin an early (and unacknowledged) exposure to Malthus on population and key arguments such as 'superfecundity' in nature and the struggle for existence ("that system of natural hostilities").

Paley's complaints about Erasmus Darwin's transformism are familiar: "... a total lack of evidence. No changes, like those which the theory requires, have ever been observed." However, in his incisive articulations of the arguments for the Creator, Paley (like Lyell later) lays out a template which, if inverted, becomes a programme for the investigation of transmutation.

These remarkable passages were intended as irony: "... A countless variety of animals might have existed, which do not exist... unicorns and mermaids, sylphs and centaurs... nations of human beings, with more or fewer fingers and toes than ten... we may modify any one species many different ways, all consistent with life, and with actions necessary to preservation, although affording different degrees of conveniency and enjoyment to the animal...". Imagine this being read by Robert Chambers, whose *Vestiges of the Natural History of Creation* (1844) in many ways broke ground for Darwin, and who was hexadactyl!

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lems involved in quantifying the impact of man on the global cycles.

The terrestrial bias may be excused in part because the immediate impact of man is most apparent on land. However, by inadvertently relegating the oceans to a secondary role, many of the feedbacks that are crucial to the stability of the biospheric cycles over the medium term are not considered. Indeed, the book deals unconvincingly with the overall potential for feedback in the natural cycles despite Smil's recognition of the "endless opportunities for interaction within and among individual cycles". The insights and provocative analyses of Lovelock in relation to feedback and regulation in the biosphere receive no mention, even though the early contributions of Vernadsky are recognized.

The book closes with an enigmatic quotation from Vernadsky in which he suggests that we are "in a transition to the noosphere", a concept related by Smil, in another quotation from Vernadsky, to "the *reconstruction of the biosphere* (my italics) in the interests of freely thinking humanity as a single totality". After reading this book I recoil from this vision! We should rather understand our dependence on these grand cycles, and learn to tread softly in their presence. □

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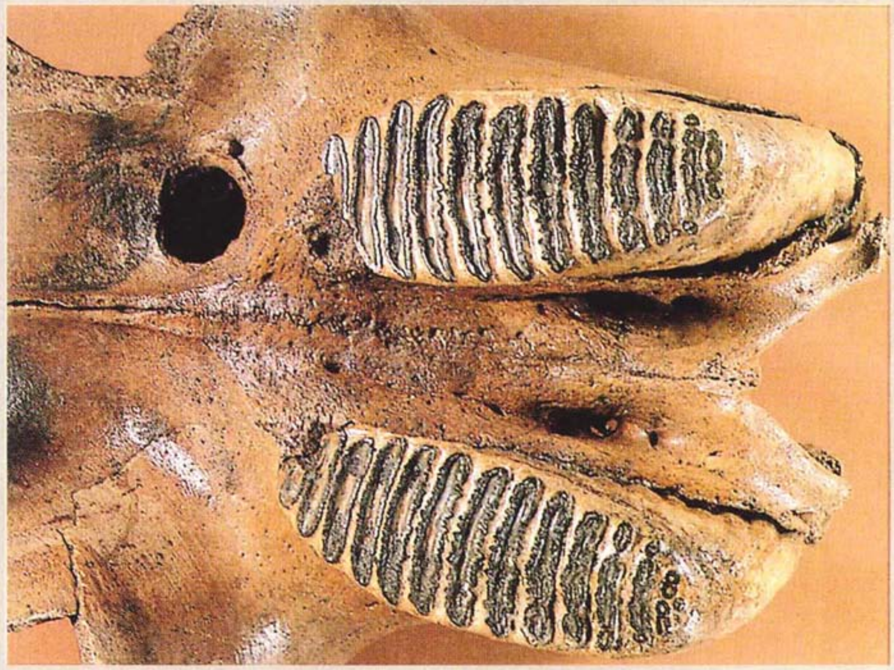

Even elephants get toothache

This fossilized jaw of *Phalaeoloxodon*, an elephant from the Pleistocene epoch, has a circular hole by the left molar caused by tooth decay. Helmut Mayr's *A Guide to Fossils* covers a wide range of fossils, and is out now in paperback (Princeton University Press, $18.95).

Microbes writ large

Life at Small Scale: The Behavior of Microbes
by David B. Dusenbery
Scientific American Library/W. H. Freeman: 1996. Pp. 214. $32.95, £19.95

Roger Whittenbury

"A word means what I want it to mean" would (with apologies to Lewis Carroll) be an apt subtitle for this book. Imprecise as the term 'microbe' is, most microbiologists — indeed biologists — would agree that at the very least a microscope rather than a magnifying glass is required to see such a creature. The author does not subscribe to this view. Idiosyncratically, he opts for a functional definition: that microbes are organisms small enough to prosper without a circulatory system. This novel definition allows him to include in his 'microbial net' beasts such as nematodes and flatworms, and is an early indication of his unconventional approach. It is, in fact, hard to say exactly what message he is seeking to convey. The book comes across largely as a compilation of the author's interests, with readers left to get from it whatever they can.

The main themes explored are how microbes move, navigate and communicate, and there are diversions into survival and feeding strategies. The result is a curious but interesting mix of detailed analyses, often with biophysical overtones (reflecting the author's background), basic commentary, and speculation. All this is accompanied by superb colour photographs and clear diagrams.

Ideally, readers should have at their side a standard text on microbiology, because the author makes generalizations that sometimes are not as all-embracing or accurate as they might have been. For instance, not all photosynthetic organisms are aerobic photoautotrophs that synthesize macromolecules from inorganic nutrients, carbon dioxide and water, releasing oxygen as a by-product. Many can photosynthesize only in the absence of oxygen, using a range of inorganic and organic electron donors other than water.

Occasional contradictory statements and apparent ambivalence on the author's part may be off-putting for the nonspecialist reader. The author says that *Synechococcus*, a photosynthetic cyanobacterium, produces oxygen in the dark and fixes nitrogen in the light, but on the next page we are told (correctly) the opposite. He also states that bacteria are too small to detect gradients of nutrients, suggesting that they have no choice but to settle for the niche in which they find themselves. Yet later on there is an extensive and excellent essay on chemotaxis, the process whereby motile bacteria can move towards or away from substances — in effect, up and down gradients. Although sensing a gradient along its surface might not be a property of a particular bacterium, the author's treatment will undoubtedly puzzle some readers.

The ability of photosynthetic organisms to coexist despite their different physiological requirements is a fascinating story of evolutionary adaptation, tailor-made for a text of this type. Sadly, by presenting the facts too briefly and too simply, the author misses this opportunity. The description of chemoautotrophs provides another example of the dangers of oversimplification. The author gives the impression that all such organisms are strict anaerobes. In fact, most are strict aerobes that play an essential part in global nutrient recycling, using oxygen as an electron acceptor in the oxidation of a wide range of inorganic compounds such as ammonia, nitrite and ferrous sulphide.

The chapter on "Locomotion without legs" is a *tour de force*, however, heavily underpinned by explanations of the way in which physical principles dictate movement in water and how small organisms have adapted to viscosity and other physical constraints. Other chapters are more variable in content and detail, and less focused.

Overall, this is an interesting but not unflawed work, filling no particular niche. The intelligent layperson will find many parts difficult to comprehend but will be charmed by others. The author clearly is not troubled by such issues. He dedicates the book "To all who share in the wonder of life on Earth"! □

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